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Mammals and their activity patterns in a forest area in the Humid Chaco, northern Argentina

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Abstract
The Humid Chaco has a high mammalian biodiversity. As habitats are threatened due to exploitation and environmental degradation, protected areas can act as refuges for wild animals. In 2006, ca 1,100 ha of gallery forest were established as the "Owl Monkey Reserve" within the private cattle ranch "Estancia Guaycoléc". The mammalian species richness and composition of the reserve was determined using direct observations, camera traps, and indirect evidence. The camera traps also allowed us to determine the activity periods of 20 of the species. Forty-two species were recorded. A fourth of those species (24%) are categorized under some risk of extinction in Argentina. While most species showed usual activity periods, 2 species (*Mazama americana* and *Tayassu pecari*) were not as exclusively nocturnal as reported from other sites, possibly due to reduced hunting pressure. The presence of various endangered species highlights the importance of protected private reserves.

Key words
Camera trap, Formosa, gallery forest, mammalian diversity, species accumulation curve, species inventory.

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Introduction

Mammals show a very high degree of diversity (Jones and Safie 2011). As in other taxa, mammal biodiversity is particularly high in the tropics, but also in the subtropics (Ceballos and Ehrlich 2006). The Humid Chaco, for example, hosts a notable diversity of wild terrestrial and aquatic animals (Ginzburg and Adámoli 2005, Adámoli et al. 2008). Out of 365 mammal species in Argentina, the provinces covering the Chaco region host the greatest species richness with 118 species (Ojeda et al. 2002). Amongst the 23 Argentine provinces, the northern Argentine province of Formosa, situated in the Humid Chaco, has the fifth highest mammalian diversity of the country (Real et al. 2003). Given the high biodiversity level, it has been proposed that the Chaco region needs to be a primary area of conservation within Argentina, while in fact the ratio of protected area to area covered is the second lowest in the country (Ojeda et al. 2002).

This lack of conservation is the more alarming as the diversity of mammalian (and other) species is threatened by various factors such as land use intensification, habitat loss and fragmentation, hunting pressures, and

competition with invasive species (Periago et al. 2014). The "defaunation" in turn can have severe functional implications for seed dispersal, forest tree composition, or spatial distribution of species, for example (Ojeda et al. 2002, Periago et al. 2014). Due to these threats, more than half of the medium-sized to large herbivorous mammals in Argentina are considered at least Near Threatened (Periago et al. 2014). Of the 28 species that are classified as Vulnerable, Endangered, or Critically Endangered in Argentina, 14 can be found within Formosa (Ojeda et al. 2012, IUCN 2013, CITES 2014).

With the aim to contribute to better planning strategies for the conservation of the Humid Chaco region, we present in this study a recent list of mammals that are present in the gallery forest of Pilagá stream in the province of Formosa, estimate the species richness, and analyse activity periods of medium-sized and large mammals.

Methods

Study site. The study took place in the Humid Chaco region. Within Argentina, the Humid Chaco covers about 170,000–200,000 km^2 in the Formosa and Chaco provinces (Ginzburg and Adámoli 2005). Its biological value results partly from its location in the transitional zone between a humid subtropical climate with Alta Paraná Atlantic forest in the eastern Chaco and a semi-arid subtropical climate with Chaco forest in the west (Placci 1995). The Humid Chaco presents a matrix of very heterogeneous environmental units, such as palm savannah, pasture, estuaries, as well as continuous and naturally fragmented forests forming forest islands (Morello and Adámoli 1968, Zunino et al. 1985, Neiff 1986, Prado 1993, Juárez 2012). Due to its environmental heterogeneity and important wetland system, this area has been considered an area of priority for the conservation of biodiversity and the sustainable development of the South American Gran Chaco (TNC 2005).

The study area is situated in eastern Formosa province in Argentina, in gallery forests that grow at the borders of the Pilagá river (25°54′ S, 058°13′ W, geodetic datum is WGS84), within the private cattle ranch "Estancia Guaycolec" (EG) owned by Bellamar Estancias S.A. (Fig. 1). The EG is a private ranch, with a rigorous surveillance and protection system of its property. Its business policy does not allow access of strangers, and people that do not belong to the ranch can only enter with special research permission.

With an area of 25,000 ha and about 25 km away from the provincial capital Formosa, the EG extensively keeps about 8,000 cattle. The area of the ranch includes all representative environmental regions of the Humid Chaco (Placci 1995). The climate is subtropical without a pronounced dry season (Chiozza and Gonzalez van Domselaar 1958, in Serra 1999). At the EG, mean annual rainfall is 1,418 mm (± 337, 1977–2013, database of the Owl Monkey Project). Mean monthly rainfall varies markedly with 2 peaks in April (197 ± 166 mm) and November (186 ± 122 mm), and a lower mean between June and August (51 ± 51 mm, database of the Owl Monkey Project). Median monthly temperatures are lower between May and August (16–18 °C) and higher between March and October (23–27 °C, database of the Owl Monkey Project). Extremely low and high temperatures are characteristic of the zone, where minimum daily temperatures less than 10 °C occur between April and September, and maximum daily temperatures greater than 33 °C between September and March (database of the Owl Monkey Project).

In 2006, the company Bellamar Estancias S.A. established in its internal division plans a restricted area called the "Owl Monkey Reserve" ("Reserva Mono Mirikiná"). This area encompasses approximately 1,100 ha of gallery forest that has undergone relatively little anthropogenic disturbances since 1996. It was kept without selective logging, but still with some disturbance factors for the functionality of the ecosystem in the form of fences to exclude cattle (*Bos taurus* Linnaeus, 1758) and Asian water buffalos (*Bubalus bubalis* Linnaeus, 1758) from the surrounding pastures and their occasional intrusion into the forest.

Sampling methods. This study presents a list of medium-sized and large mammals that were recorded between May 1996 and January 2015 (excluding the 3 domestic species cattle, water buffalo, and dog, *Canis lupus familiaris* Linnaeus, 1758, that have been recorded on the site). Our records included direct observations, photos obtained from camera traps, and indirect evidence such as spoors and post mortem findings. Additionally, we included in this list published information on small mammals obtained from a study on the diet on the spectacled owl (*Pulsatrix perspicillata* Latham, 1790) that had been conducted previously in the study area (Ramírez Llorens 2003). For the classification of the conservation status of a species, we followed the proposed categories of the International Union for Conservation of Nature (Ojeda et al. 2012, IUCN 2013). Up to 11 digital camera traps were installed (MoultrieGameSpy IR-35, IR-45, and CuddebackAttack IR) as part of an investigation to study the predators and food competitors of owl monkeys in the study area (Fig. 1). The unbaited cameras were distributed on an area of ca 97 ha (100% minimum convex polygon). The main sampling effort was inside the gallery forest (n = 189 camera-months); less sampling effort was put into a forest island of Humid Chaco forest (n = 12 camera-months) and the transitional zone between the savannah and the gallery forest (n = 14 camera-months). The cameras had been installed since 12 October 2010, and for this analysis we considered photos taken up to 8 January 2015. Cameras were activated for 24 h per day. Photos were taken automatically if an animal passed the sensor, also recording the time and date of the photo. For night-time photos, the cameras used infra-red flashes. The location of cameras was changed in irregular intervals, which resulted in a variable number of camera-days per site (range = 3–616 days, mean = 113 days, median = 40

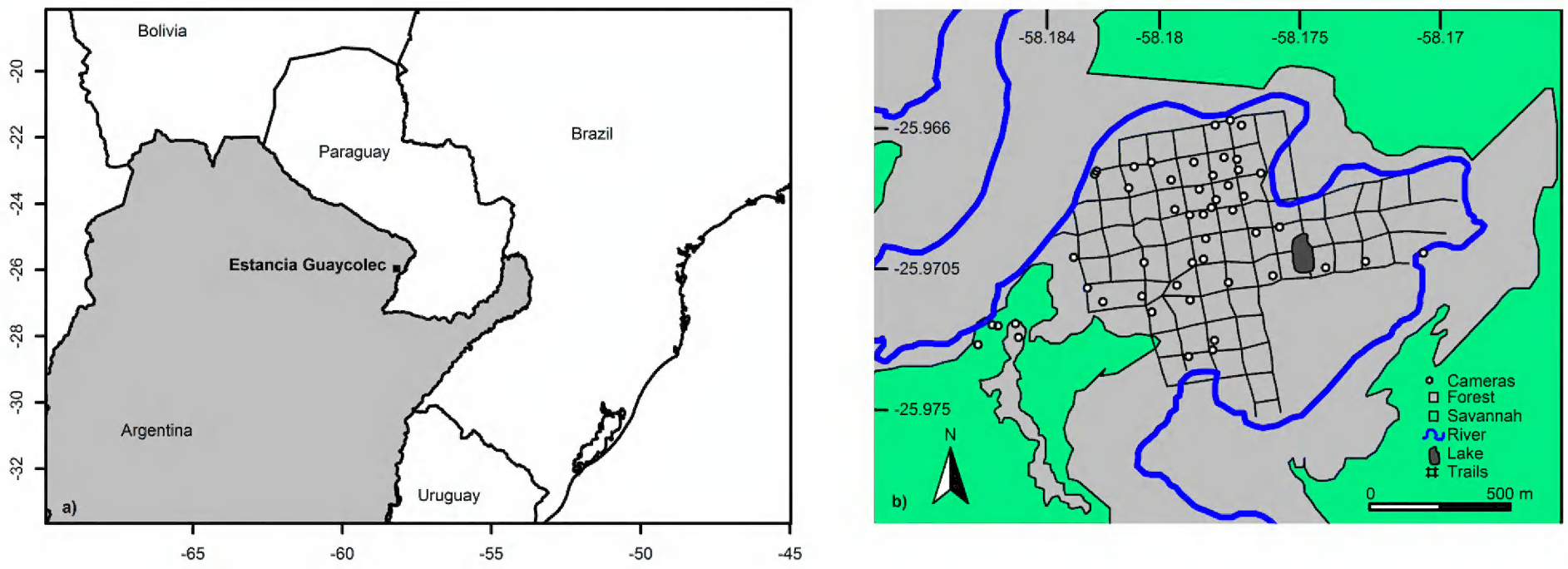


Figure 1. Location of the Guaycolec Ranch in Argentina (black quadrat in the country map: 25°54′ S, 58°13′ W), and study area within the ranch.

days) and a total of 6,439 camera-days (or 214 camera-months). For identification of animals seen directly or on photos we used various field guides (Redford and Eisenberg 1992, Emmons 1999, Bárquez et al. 2006, Canevari and Vaccaro 2007, Montero and Autino 2009).

Data analysis. For each species, the percentage of photos for each hour of the day was calculated in order to evaluate activity periods. For this analysis, only photos taken at least 60 min apart were considered independent data points, since the median time difference between photos of the same species at the same camera taken within 1 h was 2 min (with a standard deviation of 10 min around a mean of 6 min). If cameras detected a species only after the rising and before the setting of the sun, the species was classified as "diurnal". If a species was recorded only from dusk until dawn it was classified as "nocturnal". If animals were recorded at various times both during the night and during the day, they were categorized as "cathemeral" (sensu Tattersall 1987). Additionally, activity during hours of sunrise or sunset was considered "crepuscular".

The photographic evidence only allowed estimating species richness of medium-sized to large terrestrial mammals (i.e., excluding aquatic species, bats, primates, rodents and some opossums). For this evaluation, the total period of photographic records was divided into 34 periods of similar sampling effort, with each comprising approximately 200 camera days (range: 136–209 camera-days, mean: 198 camera-days, median: 202 camera-days), and for each period the number of observations of each species was counted.

Using species accumulation curves with 4 non-parametric estimators (estimators "Chao", "Jackknife 1", "Jackknife2", and "bootstrap"; reviewed by Colwell and Coddington 1994) an estimate of species richness was obtained through extrapolation. To estimate standard

Table 1. Species list of the mammals recorded at the Estancia Guaycolec, 25°54′ S, 058°13′ W. Rec = Record: direct observation (do), photo (ph), postmortem remains (re), owl pellets (op). Habitat types: savannah, palms, and grassland (Sa), Humid Chaco forest islands (Is), gallery forest (Gf), wetlands (Wt). * No habitat type was assigned since the datum stemmed from spectacled owl (*Pulsatrix perspicillata*) pellets; in some cases the scientific name changed: in Ramírez-Lorrens (2003) this was reported as: a. *Oryzomys ratticeps*, b. *Pseudoryzomys waverini*. Status categories and criteria (IUCN 2012, Ojeda et al. 2012): LC: Least Concern, NT: Near Threatened, VU: Vulnerable, EN: Endangered, CR: Critically Endangered, DD: Data Deficient. NA: Not Available. References: this study (1); Ramírez Llorens 2003 (2); Dvoskin et al. 2004 (3); Fernández-Duque et al. 2001 (4); Huck et al. 2013 (5). Species captured on camera-traps, used for estimation of species richness of terrestrial medium-sized and large mammals, are highlighted in bold.

			Habitat types				Nat'l status	No. of		
Order / family	**Scientific name**	**Rec.**	**Sa**	**Is**	**Gf**	**Wt**	**(global)**	**photos**	**Fig.**	**Ref.**
Order Didelphimorphia										
Didelphidae	***Didelphis albiventris* (Lund, 1840)**	do, ph, op		x	x		LC (LC)	191	5	1, 2
	Didelphis aurita (Wied-Neuwied, 1826)	op			x		LC (LC)			2
	***Philander opossum* (Linnaeus, 1758)**	do, ph, op			x		LC (LC)	19	6	1, 2
	Marsupial non det.			x	x			92		1
Order Cingulata										
Dasypodidae	***Dasypus novemcinctus* (Linnaeus, 1758)**	do, ph, re	x	x	x		LC (LC)	91	7	1
	Tolypeutes matacus (Desmarest, 1804)	do, re	x	x			NT (NT)		8	1
Order Pilosa										
Myrmecophagidae	***Myrmecophaga tridactyla* (Linnaeus, 1758)**	do, ph	x	x	x		VU A2c+3c (VU A2c)	22	9	1
	***Tamandua tetradactyla* (Linnaeus, 1758)**	do, ph, re	x	x	x		NT (LC)	6	10	1

Continued

Table 1. *Continued.*

Order / family	Scientific name	Rec.	Habitat types				Nat'l status (global)	No. of photos	Fig.	Ref.
			Sa	Is	Gf	Wt				
Order Chiroptera										
Molossidae	*Eumops perotis* (Schinz,1821)*	op					LC (LC)			2
	Molossus rufus (E. Geoffroy, 1805)*	op					NA (NA)			2
Phyllostomidae	*Tonatia* sp. (Gray, 1827)*	op					DD			2
Order Primates										
Atelidae	*Alouatta caraya* (Humboldt, 1812)	do, re		x	x		VU A4cd, C2a(i) (LC)		11	3
Cebidae	*Aotus azarae* (Humboldt, 1811)	do, re		x	x		LC (LC)		12	4
Order Lagomorpha										
Leporidae	***Sylvilagus brasiliensis* (Linnaeus, 1758)**	do, ph	x	x	x		LC (LC)	201	13	1
Order Rodentia										
Suborder Sciurognathi										
Muridae	Small non-identified rodents	ph		x	x			127		
	Akodon azarae (Fischer, 1829)*	op					LC (LC)			2
	Akodon cf. A. cursor (Winge, 1887)*	op					DD (LC)			2
	Calomys callosus (Rengger, 1830)*	op					LC (LC)			2
	Holochilus chacarius (Thomas, 1906)*	op					LC (LC)			2
	Oligoryzomys chacoensis (Myers & Carleton, 1981)*	op					LC (LC)			2
	Oligoryzomys cf O. microtis (Allen, 1916)*	op					LC (LC)			2
	Sooretamys angouya (Fischer, 1814)*a	op					LC (LC)			2
	Pseudoryzomys simplex (Winge, 1887)*b	op					LC (LC)			2
	Scapteromys aquaticus (Thomas 1920)*	op					LC (LC)			2
	Oecomys sp.	op					NA			2
Suborder Hystricognathi										
Hydrochaeridae	***Hydrochoerus hydrochaeris* (Linneaus, 1766)**	do, ph	x	x	x	x	NT (LC)	10	14	1
Myocastoridae	*Myocastor coypus* (Molina, 1782)	do	x				LC (LC)			1
Cuniculidae	***Cuniculus paca* (Linnaeus, 1766)**	ph, re			x		NT(LC)	22	15	1, 5
Order Perissodactyla										
Tapiridae	***Tapirus terrestris* (Linnaeus, 1758)**	do, ph	x	x	x		EN A3c+4ce (VU A2cde+3cde)	47	16	1
Order Artiodactyla										
Tayassuidae	***Pecari tajacu* (Linnaeus, 1758)**	do, ph, re		x	x		VU A3cd (LC)	36	17	1
	***Tayassu pecari* (Link, 1795)**	do, ph		x	x		EN A2abcd+3cd+4cd (VU A2bcde+3bcde)	257	18	1
Cervidae	*Blastocerus dichotomus* (Illiger, 1815)	do	x				VU A2 (VU A4acde)		19	1
	***Mazama americana* (Erxleben, 1777)**	do, ph	x	x	x		NT (DD)	30	20	1
	***Mazama gouazoubira* (Fischer, 1814)**	do, ph		x	x	x	LC (DD)	11	21	1
Order Carnivora										
Canidae	***Cerdocyon thous* (Linnaeus, 1766)**		x	x	x		LC (LC)	13	22	1
	***Chrysocyon brachyurus* (Illiger, 1815)**	ph, re	x				EN A1acde+2ce; C2a (NT)	1	23	1
Felidae	***Herpailurus yagouaroundi* (Geoffroy Saint-Hilaire, 1803)**	do, ph, re	x	x	x		LC (LC)	2	24	1
	***Leopardus pardalis* (Linnaeus, 1758).**	do, ph			x		NT (LC)	79	25	1
	***Leopardus geoffroyi* (d'Orbigny & Gervais, 1844)**	ph		x	x		LC (LC)	5	26	1
	***Puma concolor* (Linneaus, 1771)**	do, ph,	x	x	x		LC (LC)	28	27	1
Mustelidae	*Lontra longicaudis* (Olfers, 1818)	do			x		EN A1 acde, B12abcde+3b, C2a (DD)		28	1
	***Eira barbara* (Linnaeus, 1758)**	do, ph, re		x	x		EN (LC)	59	29	1
Procyonidae	***Nasua nasua* (Linnaeus, 1766)**	do, ph	x	x	x		LC (LC)	535	30	1
	***Procyon cancrivorus* (Cuvier, 1798)**	do, ph	x		x		VU A1ace; C2a (LC)	7	31	1

errors, the data were permuted 10,000 times. This analysis was conducted using the programme R version 3.1.1 with the package 'vegan' (Oksanen et al. 2014, R Core Team 2015).

Results

We recorded 42 mammalian species from 18 families and 10 orders either by direct sightings, by camera-trap

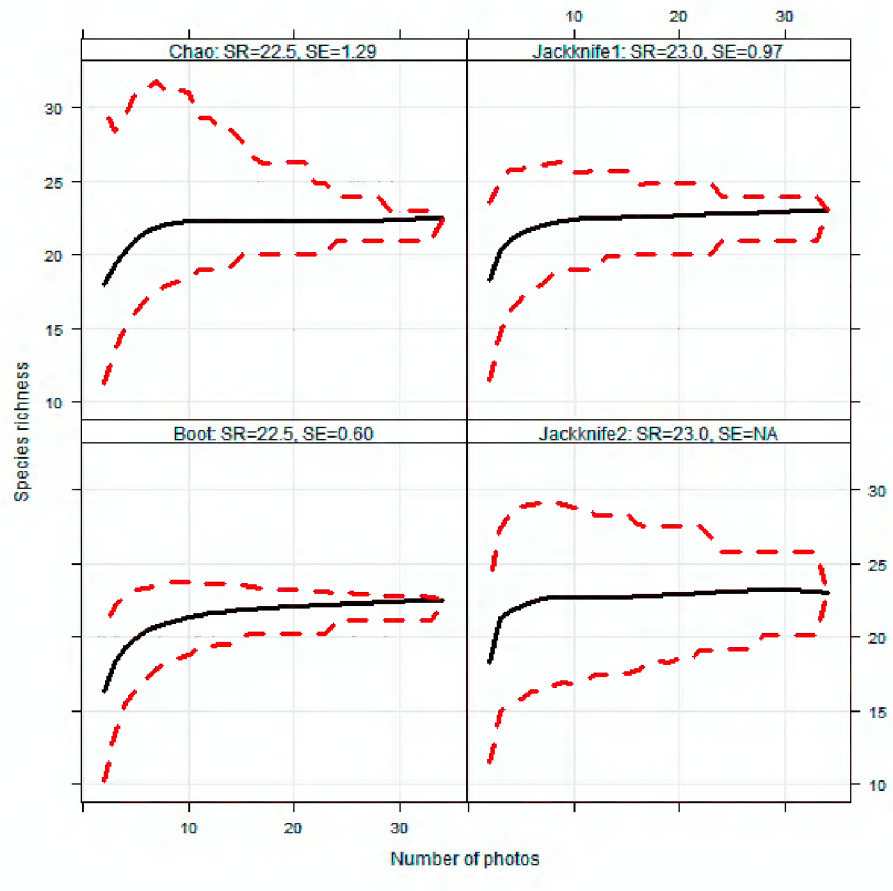


Figure 2. Species accumulation curves to estimate species richness (SR) of mammals at the Estancia Guaycolec using four estimators. SE = standard error.

recordings, or from remains in owl pellets (see Table 1 for details).

Approximately a quarter (24%) of these 42 species belonged to conservation-relevant categories that indicate some risk of extinction in Argentina (Vulnerable or Endangered), and 10% were considered Vulnerable at a global level (Table 1). We recorded 5 of the 12 species considered Endangered in the Red List of Threatened Mammals of Argentina (Ojeda et al. 2012), 5 of the 12 Vulnerable, 6 classified as Near Threatened, and 22 of Least Concern (Table 1). Additionally, for 4 species there were not sufficient data available for classification, or the species was not listed in the book (Ojeda et al. 2012).

Based on the 34 periods of 200 camera days each, the species accumulation curves, using the 4 different estimators, estimated species richness of medium-sized and large terrestrial mammals to be between 22 and 23 (Fig 2), compared to the 22 species caught with the camera traps.

We distinguished 3 activity periods for species recorded with camera-traps: diurnal, nocturnal and cathemeral (Figs 3, 4). According to its percentage activity level, the tayra (*Eira barbara* Linnaeus, 1758; N = 78 photos; Fig. 3A) was classified as diurnal. Within the felids, the jaguarundi (*Herpailurus yagouaroundi* Geoffroy Saint-Hilaire, 1803) was only registered twice, on both occasions during day-time (11:15 h and 13:15 h; not included in Fig. 3). All records of Geoffroy's cats (*Leopardus geoffroyi* d'Orbigny & Gervais, 1844) were from the second half of the night after midnight (n = 5, Fig. 3A), while both puma (*Puma concolor* Linnaeus, 1771; n = 30) and ocelot (*Leopardus pardalis* Linnaeus, 1758; n = 81) were mainly recorded during the night, but also with several records during the day, so that they were considered cathemeral (Fig. 3A).

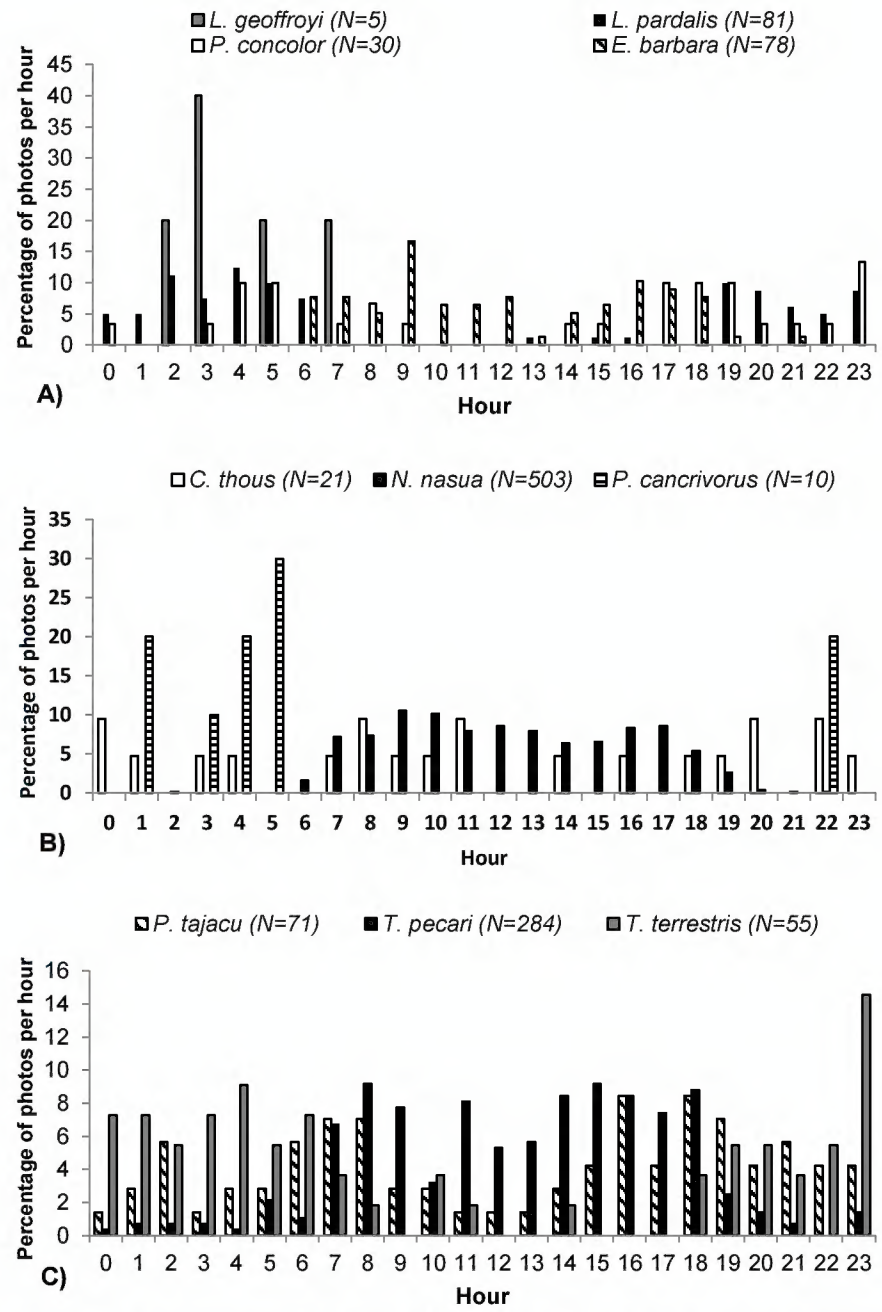


Figure 3. Activity periods for (**A**) Geoffroy's cat, ocelot, puma and tayra, (**B**) crab-eating fox, ring-tailed coati and crab-eating raccoon, (**C**) collared peccari, white-lipped peccari and tapir.

Crab-eating raccoons (*Procyon cancrivorus* Cuvier, 1798) were only recorded during the night (N = 10), while ring-tailed coatis (n = 503) were nearly exclusively diurnal (Fig. 3B). In contrast, the crab-eating fox was clearly cathemeral with photos taken over the whole day (n = 21, Fig. 3B).

Lowland tapirs (*Tapirus terrestris* Linnaeus, 1758; n = 55), collared peccaries (*Pecari tajacu* Linnaeus, 1758; n = 71) and white-lipped peccaries (*Tayassu pecari* Link, 1795; n = 284) were likewise cathemeral (Fig. 3C). However, the main peak of activity of tapirs and collared peccaries was during the night, while the main peak of activity of white-lipped peccaries was during day-time (Fig. 3C).

The red brocket deer (*Mazama americana* Erxleben, 1777; n = 35) could be observed throughout the 24 h of a day, while records of the grey brocket deer (*Mazama gouazoubira* Fischer, 1814; n = 10) were mainly diurnal (Fig. 4A). Additional 92 photos of unspecified deer were mainly taken during the night, when it was more difficult to accurately distinguish between red and grey brocket deer. A further deer species, the marsh deer (*Blastocerus dichotomus* Illiger, 1815) was not recorded with the camera-traps that were mainly within the gallery forest, but was occasionally observed in the savannah as well as in gallery forest, always during daytime.

Amongst the Pilosa and Cingulata, the nine-banded

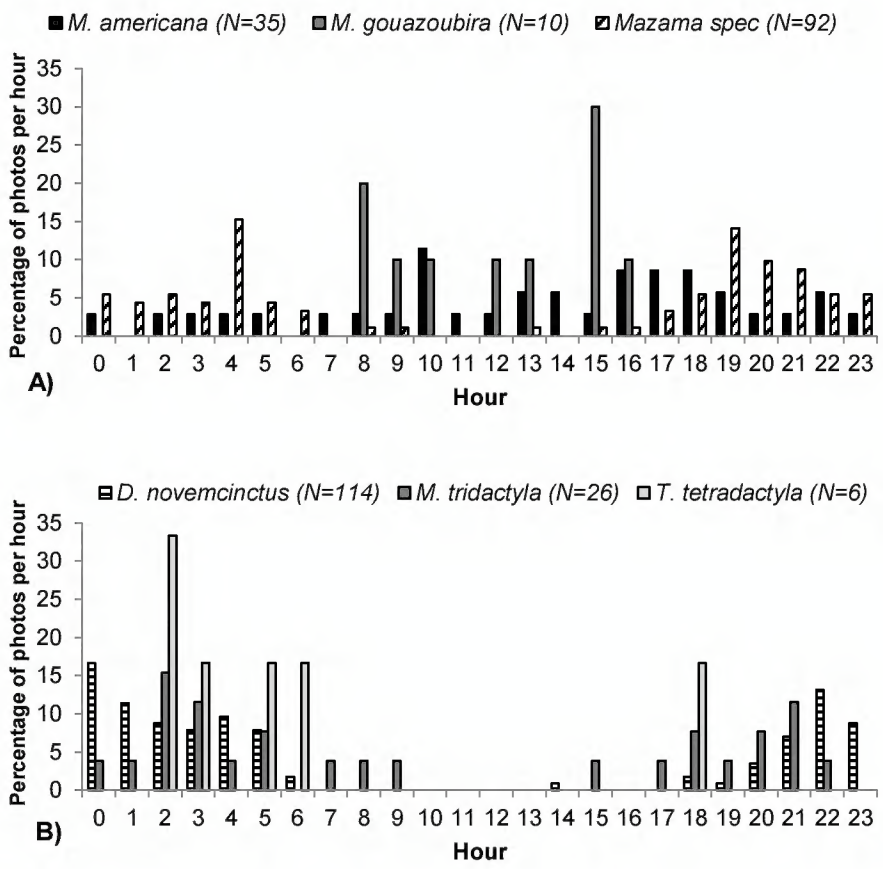


Figure 4. Activity periods for: (**A**) red brocket deer and grey brocket deer, (**B**) nine-banded armadillo, giant anteater and Southern tamandua, (**C**) capybara, paca, Brasilian cotton-tail rabbit, white-eared opossum, grey four-eyed opossum and murid rodents.

armadillo (*Dasypus novemcinctus* Linnaeus, 1758; n = 114) and the Southern tamandua (*Tamandua tetradactyla* Linnaeus, 1758; n = 7) were recorded nearly exclusively during the night (Fig. 4B), although there were also a few direct observations of the tamandua during early hours of the morning (n = 8 observations over 20 years of field work at the study area). The giant anteater (*Myrmecophaga tridactyla* Linnaeus, 1758) appeared cathemeral, with occasional observations in the morning until 1000 h, or in the afternoon between 1400 h and 1600 h, but the majority during the night (n = 26, Fig. 4B).

Amongst the "small" mammals, murine rodents and the paca (*Cuniculus paca* Linnaeus, 1766; n = 22), marsupials (white-eared opossum *Didelphis albiventris* Lund, 1840, n = 188; and grey four-eyed opossum *Philander opossum* Linnaeus, 1758, n = 20), and the Brazilian cotton-tail (or tapeti) rabbit (*Sylvilagus brasiliensis* Linnaeus, 1758; n = 187), all showed an exclusively nocturnal activity period (Fig. 4C). Only the capybara (*Hydrochoerus hydrochaeris* Linnaeus, 1766; n = 10) was also recorded and directly observed during daytime, and can thus be classified as cathemeral (Fig. 4C).

Order Didelphimorphia
Family Didelphidae

Didelphis albiventris Lund, 1840: 20; Figure 5

The white-eared opossum is identified as a large-bodied marsupial with pale ears and fur extending several centimetres from the base of the tail. White-eared opossums have prominent black markings on their face.

Didelphis aurita Wied-Neuwied, 1826: 395

The big-eared opossum is similar to the white-eared opossum but has black, furless ears, and the tail, which is also furred at the base like the one of *D. albiventris*, is half black and half white.

Philander opossum Linnaeus, 1758: 55; Figure 6

Compared to the *Didelphis* opossum the grey four-eyed opossum is smaller, has striking white spots over the eye, and a bi-coloured tail.

Order Cingulata
Family Dasypodidae

Dasypus novemcinctus Linnaeus, 1758: 51; Figure 7

As the name suggests, the nine-banded armadillo features 9 clear bands within its greyish shell. This armadillo has a fairly long snout and a rather long tail that starts thick and steadily becomes thinner.

Tolypeutes matacus Desmarest, 1804: 28; Figure 8

Compared to the nine-banded armadillo the Southern three-banded armadillo is much smaller. It is capable of forming a complete ball to protect itself from predators. If not in a ball, 3 distinctive bands on the back can be seen in its shell, which is usually of a light beige-brown colour.

Order Pilosa
Family Myrmecophagidae

Myrmecophaga tridactyla Linnaeus, 1758: 35; Figure 9

The giant ant-eater has a very distinctive shape, with a very narrow, long snout, and a very bushy, long-haired tail. Front claws are enlarged and curled back. The fur is brownish-grey, with black bands along the wrist, and white stripes behind the ears towards the shoulder.

Tamandua tetradactyla Linnaeus, 1758: 35; Figure 10

The Southern tamandua is smaller in size than the giant ant-eater, and has less long hair of a more golden-blond with a black "vest", although the colouration may vary. The snout, while still elongated, is less long than those of the anteater, and the prehensile tail is sparsely haired.

Order Chiroptera
Family Molossidae

Eumops perotis Schinz, 1821: 870

Identification was based on spectacled owl pellet remains as reported in Ramírez-Llorens (2003).

Molossus rufus E. Geoffroy, 1805: 155

Synonym. *Molossus ater* E. Geoffroy, 1805; see Dolan (1989) for problems with nomenclature of the species.

Identification was based on spectacled owl pellet

Figures 5–10. Photographs of mammals directly observed or determined by camera-traps. **5**. White-eared opossum, *Didelphis albiventris.* **6**. Grey four-eyed opossum, *Philander opossum.* **7**. Nine-banded armadillo, *Dasypus novemcinctus.* **8**. Southern three-banded armadillo, *Tolypeutes matacus.* **9.** Giant anteater, *Myrmecophaga tridactyla.* **10.** Southern tamandua, *Tamandua tetradactyla.*

remains as reported in Ramírez Llorens (2003), who used the synonym *M. ater*.

Family Phyllostomidae

Tonatia sp. Gray, 1827: 71

Identification to genus level was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Order Primates
Family Atelidae

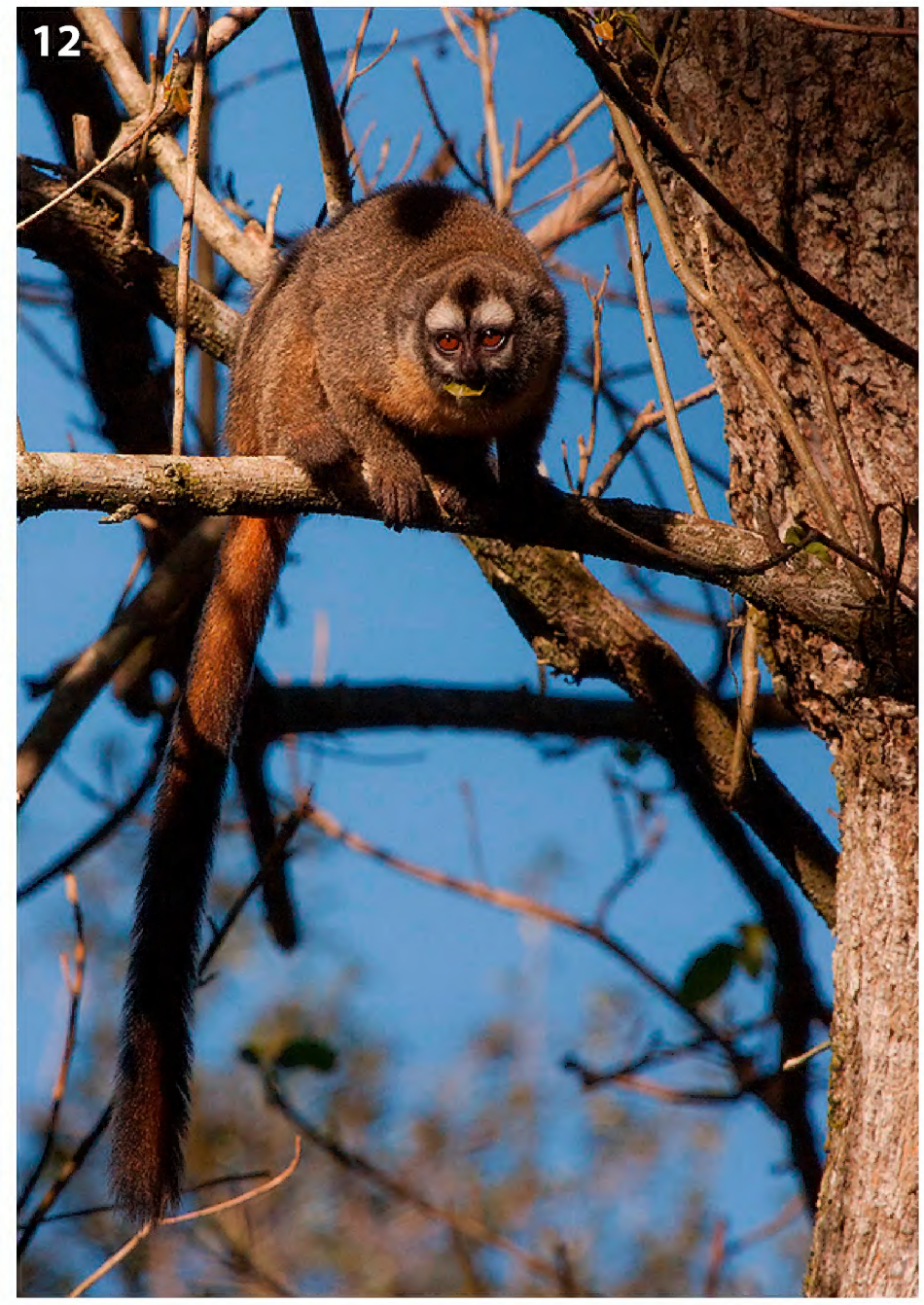
Alouatta caraya Humboldt, 1812: 355; Figure 11

The medium-sized black-and-golden howler monkey is a sexually dichromatic species with black males and yellow-buff females and juveniles. Adult males have a large "chin sack" enabling them to produce the name-giving loud vocalizations. Howler monkeys have prehensile tails.

Family Cebidae

Aotus azarae Humboldt, 1811: 359; Figure 12

Azara's owl monkeys are smaller than howler monkeys. They have minimal sexual dimorphism with light brown fur and a black and white face mask (particularly above the very large eyes).



Figures 11–15. Photographs of mammals directly observed or determined by camera-traps. **11.** Black and gold howler monkey, *Alouatta caraya*. **12.** Azara's owl monkey, *Aotus azarae*. **13.** Brazilian cotton-top rabbit, *Sylvilagus brasiliensis*. **14.** Capybara, *Hydrochoerus hydrochaeris*. **15.** Paca, *Cuniculus paca*.

Order Lagomorpha
Family Leporidae

Sylvilagus brasiliensis Linnaeus, 1758: 58; Figure 13

The tapeti or Brazilian cotton-tail rabbit is a fairly small lagomorph with long ears (albeit not if compared to other lagomorphs). Its fur is agouti-brown with a black tail. While the systematics of *S. brasiliensis* has recently been questioned and no analyses have been conducted with specimen from this locality, individuals from Paraguay, the closest location investigated, were considered *S. brasiliensis* (Ruedas et al. 2017).

Order Rodentia
Family Muridae

Akodon azarae Fischer, 1829: 325

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

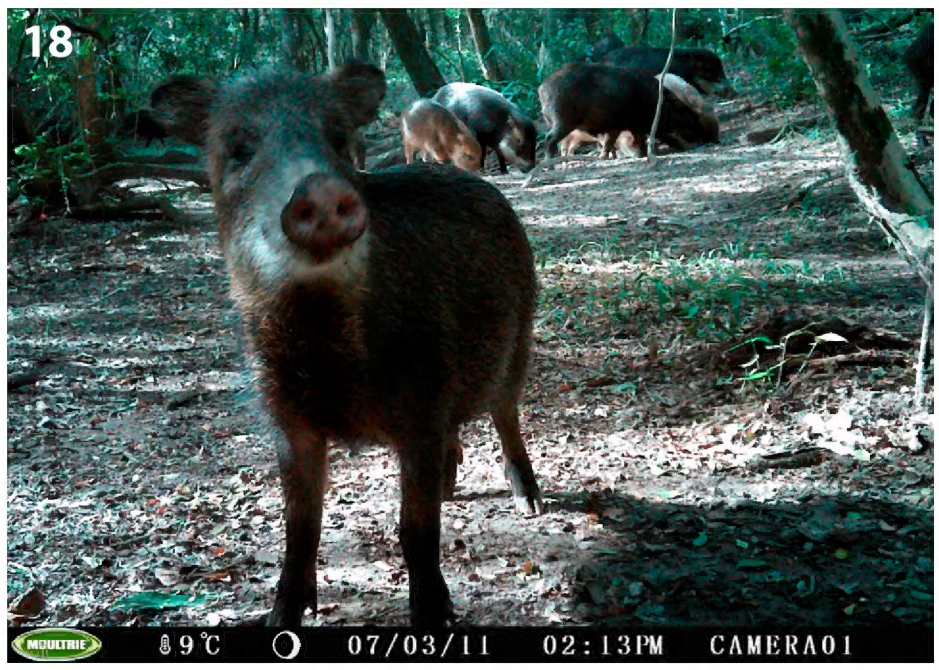
Akodon cf. ***A. cursor*** Winge, 1887: 25

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Calomys callosus Rengger, 1830: 231

Location. 25°54′ S, 58°13′ W.

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).



Figures 16–21. Photographs of mammals directly observed or determined by camera-traps. **16.** Lowland tapir, *Tapirus terrestris* **17.** Collared peccary, *Pecari tajacu.* **18.** White-lipped peccary, *Tayassu pecari.* **19.** Marsh deer, *Blastocerus dichotomus.* **20.** Red brocket deer, *Mazama americana.* **21.** Grey brocket deer, *Mazama gouazoubira.*

Holochilus chacarius Thomas, 1906: 446

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Oligoryzomys chacoensis Myers & Carleton, 1981: 19

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Oligoryzomys cf. ***microtis*** J.A. Allen, 1916: 525

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Sooretamys angouya Fischer, 1814: 71

Synonyms. *Oryzomys angouya* Fisher (1814); *Oryzomys ratticeps* Hensel (1872); for classification see Musser and Carleton (2005). The genus placement follows Percequillo et al. (2016).

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003). The genus name is following the usage of Percequillo et al. (2016).

Pseudoryzomys simplex Winge, 1887: 11

Synonym: *Pseudoryzomys wavrini* Thomas (1921); for classification see Voss and Myers (1991)

Identification was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Scapteromys aquaticus Thomas, 1920: 477

Based on remains as reported in Ramírez Llorens (2003).

Oecomys sp. Thomas, 1906: 444

Identification to the genus level was based on spectacled owl pellet remains as reported in Ramírez Llorens (2003).

Family Hydrochaeridae

Hydrochoerus hydrochaeris Linnaeus, 1766: 103; Figure 14

The world's largest rodent, the capybara, has the appearance of a very large, long-legged guinea-pig (*Cavia porcellus*), with a large head, sturdy body, and no tail. The fur is brown.

Family Myocastoridae

Myocastor coypus Molina, 1782: 287

The coypu or nutria is smaller than the capybara but still a fairly large rodent that, apart from the more rat-like tail, resembles a beaver (*Castor* spp.). The coypu has brown fur with a white muzzle, and webbed feet.

Cuniculus paca Linnaeus, 1766: 81; Figure 15

Another medium-sized rodent in the area is the lowland paca that has a reddish to dark-brown fur on the back, lighter colour at the underbelly, and 3 to 5 rows of distinctive white spots at its side. Like capybaras, pacas do not have a tail and have the general appearance of a long-legged, large guinea-pig.

Order Perissodactyla
Family Tapiridae

Tapirus terrestris Linnaeus, 1758: 74; Figure 16

The largest mammal in the area is the South American tapir. It is dark grey-brown with very sparse, coarse hair that forms a short crest along the neck. The flexible nose forms a short trunk. The ears are round and, otherwise dark, have a white edge.

Order Artiodactyla
Family Tayassuidae

Pecari tajacu Linnaeus, 1758: 50; Figure 17

Three pig (*Sus scrofa* Linnaeus, 1758)-like species are found in Formosa. The Chacoan peccary (*Catagonus wagneri* Rusconi 1930) does not occur in the East of the province. The 2 other species have both coarse, bristly brown hair that is longer along the neck and can be raised to a crest if excited, and a flexible snout that ends in a disk. The collared peccary has a white band of fur around its neck and is somewhat smaller than the white-lipped peccary (*Tayassu pecari*).

Tayassu pecari Link 1795: 104; Figure 18

The white-lipped peccary is larger than the collared peccary, but otherwise similar in appearance. However, it has white markings along the snout and cheek, and no white collar.

Family Cervidae

Blastocerus dichotomus Illiger, 1815: 117; Figure 19

The marsh deer is the largest of the South American deer species. It has a reddish-brown fur, with darker legs. Around the eyes, ears, and below the chin, are white marks, whereas the muzzle is black. Males have forked antlers.

Mazama americana Erxleben, 1777: 324; Figure 20

The red brocket deer likewise has reddish fur, partially black legs and a white underside to its tail. Head-body length is between 104 and 144 cm. Antlers of males are spiked and small.

Mazama gouazoubira Fischer, 1814: 465; Figure 21

The smaller grey brocket deer (head-body length of 82–125 cm) has dark brown or greyish-brown fur with only a hint of red, with lighter grey or white undersides. The bottom of the tail is white.

Order Carnivora
Family Canidae

Cerdocyon thous Linnaeus, 1766: 60; Figure 22

The crab-eating fox is a medium-sized canid. Its short, thick fur is greyish-brown but can also be pale and yellowish, with black tips to ears and the bushy tail. In contrast to the pampas fox (*Lycalopex gymnocercus* Fischer, 1814), the crab-eating fox has black legs with a black stripe along the hind feet, whereas the pampas fox has greyish-brown fur on its body with paler undersides and its lower hind limb has a black spot but otherwise the legs are not black apart from the final part of the feet.

Chrysocyon brachyurus Illiger, 1815: 121; Figure 23

The maned wolf is the largest South American canid species. Its fur is reddish-brown, with longer, darker hair along its neck that forms a crest or mane that can be raised. Compared to other canids it has particularly long legs that are black at the lower ends.

Family Felidae

Herpailurus yagouaroundi Geoffroy Saint-Hilaire, 1803: 124; Figure 24

The jaguarundi is a somewhat odd looking small felid with a more elongated head and slightly shorter legs than typical for felids of that size. Two colour morphs exist, with uniformly greyish-black or red-brown fur.

Leopardus pardalis Linnaeus, 1758: 1:42; Figure 25

Of a more typical feline appearance is the ocelot, a medium-sized cat, with cream to beige fur and black blotches. The tail is ringed and can end in a black or a white tip. As with most other felids, melanistic forms can occur.

Leopardus geoffroyi d'Orbigny & Gervais, 1844: 40; Figure 26

The Geoffroy's cat has the size of a domestic cat (*Felis silvestris catus* Linnaeus, 1758). It has a similar background colouration as the ocelot, but rather small black spots.

Figures 22–27. Photographs of mammals directly observed or determined by camera-traps. **22.** Crab-eating fox, *Cerdocyon thous*. **23.** Maned wolf, *Chrysocyon brachyurus*. **24.** Jaguarundi, *Puma yagouaroundi*. **25.** Ocelot, *Leopardus pardalis*. **26.** Geoffroy's cat, *Leopardus geoffroyi*. **27**. Puma, *Puma concolor*.

Puma concolor Linnaeus, 1771: 2: 522; Figure 27

The puma is the second largest felid in the Neotropics. It has a uniformly reddish-brown, silvery, or beige fur and lighter fur on the underbelly and around the muzzle; the tone of the fur varies between individuals. In contrast, the largest felid is the jaguar. The jaguar is much stockier than the puma and has a base colouration of tawny-beige with white underparts and distinctive black rosettes, which on the tail can form rings.

Family Mustelidae

Lontra longicaudis Olfers, 1818: 233; Figure 28

The semi-aquatic river otter has dark brown-grey, short hair, with lighter colouration around the throat and muzzle. Legs are short, and the tail is long and rather stout. Its feet are fully webbed.

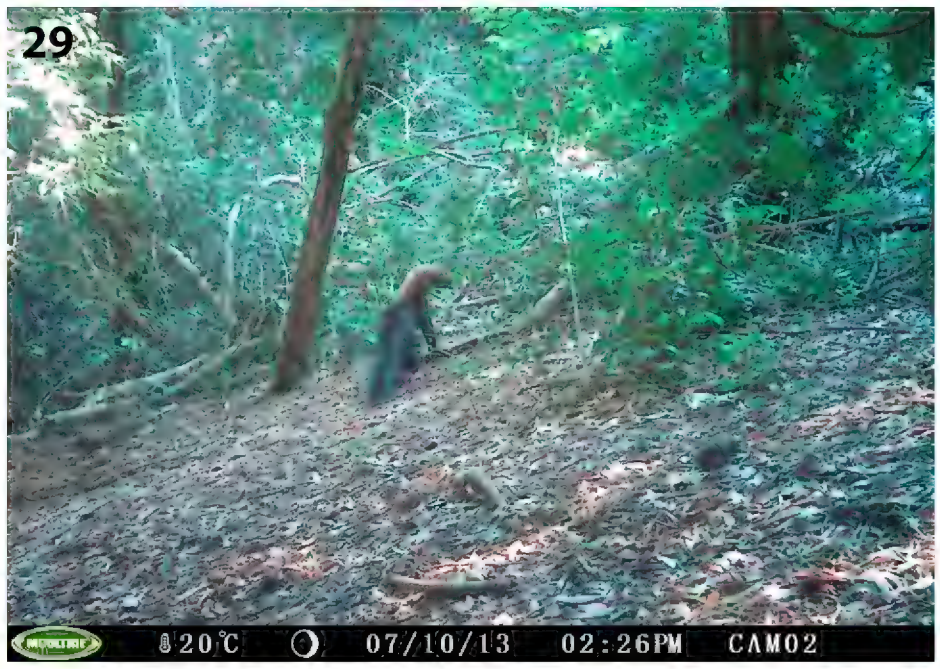
Eira barbara Linnaeus, 1758: 46; Figure 29

The largest (semi) arboreal mustelid in the world is the tayra, which has brown fur, with an often paler head and a beige chest patch. It has the typical long, slender, short-legged, and long-tailed form of martens (*Mustela* spp.).

Family Procyonidae

Nasua nasua Linnaeus, 1766: 64; Figure 30

The ring-tailed coati has agouti-brown fur with lighter undersides, and a distinctive banded, thick tail. The nose



Figures 28–30. Photographs of mammals directly observed or determined by camera-traps. **28.** River otter, *Lontra longicaudis*. **29.** Tayra, *Eira barbara*. **30.** Ring-tailed coati *Nasua nasua*. **Figure 31.** Crab-eating raccoon, *Procyon cancrivorus*.

is elongated. In contrast to the white-nosed coati (*Nasua narica* Linnaeus, 1766), the muzzle is rather darker and not white.

Procyon cancrivorus Cuvier, 1798: 113; Figure 31

Crab-eating raccoons have thick grey fur, black legs, a black-and-white banded tail, and a distinctive black face mask around the eyes that is bordered by a white band above the eyes and a white ring around the muzzle.

Discussion

The species record of the "Owl Monkey Reserve" clearly shows that this privately protected area serves as an important reservoir of biodiversity in the Green Biological Corridor (Pilagá-Monte Lindo) that has been identified in the "Plan de Ordenamiento Territorial" of the Formosa province (POT-For; Ministerio de la Producción y Ambiente de la Provincia de Formosa, 2010). The ranch, in general, and the reserve, in particular, host an important diversity of species that represents nearly all medium-sized and large mammals cited for the wetland zone of the courses within the delta Bermejo-Pilcomayo (Emmons 1990, Redford and Eisenberg 1992, Ojeda et al. 2012). This includes 4 of the 12 species classified as Endangered in Argentina (maned wolf, lowland tapir, white-lipped peccary, and river otter) and 5 of the 12 classified as vulnerable (Marsh deer, giant anteater, black and gold howler monkey *Alouatta caraya* Humboldt 1812, crab-eating raccoon, and collared peccary) (Ojeda et al. 2012, IUCN 2013, CITES 2014). This means that with 39 recorded terrestrial mammals the EG harbours about 2/3 of the 61 terrestrial mammals previously listed for Formosa in a study compiling data from various previous studies and therefore over a much longer time period (Real et al. 2003). This value is likely to be an underestimate for species richness in the EG, because while confirmation of larger mammals could be done through various methods, including camera-traps, small mammals (as well as bats) were only recorded based on a previous study using owl pellets from spectacled owls (Ramírez-Llorens 2003). Small mammals not or not commonly being preyed upon by spectacled owls were therefore likely to be missed in our study.

As the EG lies within the Green Biological Corridor it is possible that it protects two further important species that are very rare and difficult to observe. For example, it is possible that the jaguar (*Panthera onca* Linnaeus 1758) irregularly passes the area. The cowboys of the ranch assert that they have seen this felid in parts of the ranch further away from our study site, and in 2003 one individual was caught near the ranch. We also included in our species list the marsh deer (Table 1) even though it was not recorded with the camera traps, because this part of the gallery forest is relatively far away from the

wetlands that are preferred by the species. Yet we did observe individuals of this species on several occasions in the transitional zone between wetlands and pasture very close to the gallery forest, and twice even within the gallery forest.

The activity periods deduced from the photographic records largely confirm observations from other studies (ocelot: cathemeral in the general species account by Murray and Gardner 1997; tayra: diurnal Konecny 1989, Presley 2000; giant anteater: cathemeral in the Pantanal and Serra de Canastra National Park of Brazil, Mourão and Medri 2007, Shaw et al. 2014, lowland tapir: cathemeral in the Atlantic Forest of Brazil, Ferreguetti et al. 2017). The 2 records of the jaguarundi which were both taken during daytime are also in line with a study from Belize that found mainly diurnal activity (Konecny 1989). Nevertheless, our records suggest that some of the species could be more flexible in their activity period than suggested from other studies. In particular, 2 species that in other areas showed nocturnal behaviour were cathemeral at our study site: In the Atlantic forest of Brazil, where the grey brocket deer was diurnal as found in our study, the red brocket deer was primarily nocturnal (Ferreguetti et al. 2015), whereas at our study site it was observed both night and day. Even if all unidentified deer photos, that were mainly taken at night, would be considered to be representing red brocket deer, still about 40% of the photos of the species were taken between 0700 and 1900 h. Likewise, white-lipped peccaries are usually described as nocturnal (see species record by Mayer and Wetzel 1987), and a study in the Paraguayan Chaco, i.e. in a comparable habitat type, recorded that collared peccaries were diurnal and crepuscular, resting only during the hottest hours during daytime (Taber et al. 1994). Our study indicates that both species can be active during both night and day. Shifts in activity periods can sometimes be attributed to predation pressures (Clark 1983, Starr et al. 2012). However, this is an unlikely explanation for these species at the Estancia Guaycolec, because both puma and ocelot were cathemeral, and activity patterns throughout the day of ocelot and deer or peccaries did not significantly differ (Huck et al. 2016). Instead, the observed differences might be due to the absence of human hunting pressure in the Owl Monkey Reserve of the EG (Owl Monkey Project, pers. obs.). In contrast, both deer species were hunted in the Brazilian Atlantic Forest (Ferreguetti et al. 2015) which could have caused the red brocket deer to be more strictly nocturnal than at our study site. Similarly, both peccary species are hunted in many areas but, in particular, the larger white-lipped peccary seems to be more affected by human hunting (Perez 1996). This might explain why without human hunting pressure it showed more diurnal activity in the EG than usually observed. While in the case of activity patterns of deer and peccaries it is not clear which population actually changed their behaviour (and whether it was truly due human hunting pressure), changes in behaviour can be relevant for conservation: behavioural changes can directly affect fitness, may indirectly influence other fitness-relevant behaviours, or may even modify the dynamics of larger species communities (Berger-Tal et al. 2011). It would therefore be important to understand what the "natural" activity periods of species are that are commonly observed only at night in areas with high anthropogenic impact, and how shifted activity patterns affect the species.

To further increase relevant knowledge about species and generally ecological regions and to be able to develop and implement adequate protection plans, it is important to document all information on biodiversity in a zone, in particular if it has such a high biodiversity level as the Chaco region, but suffers from one of the highest levels of degradation of the country (Bertonatti and Corcuera, 2000, Real et al. 2003, Ginzburg and Adámoli, 2005). The information provided in this study helps to evaluate the conservation status of different species. For example, in Argentina, the collared peccary is considered a vulnerable species, and the white-lipped peccary to be near threatened (Ojeda et al. 2012, IUCN 2013). Yet the latter species appears much more commonly on photos, which suggests the possibility that it is more abundant in the gallery forests of the EG, since both species use similar habitat types (Desbiez et al. 2009). While both species prefer wooded areas far away from urban centres, collared peccaries appear to be generally more common in the Argentine Chaco and seem to be less susceptible to human disturbances (Altrichter and Boaglio 2004). Possibly, the white-lipped peccary, as the more dominant species (Keuroghlian et al. 2004), but also being bigger and living in larger groups, favours areas with little anthropogenic influences, which has also been suggested in a study for a population in Lowland Amazonian forests (Perez 1996).

From a conservation point of view, the EG, with its strict access policies, could therefore act as a refuge within the area, since other similar ranches in the vicinity do not offer this degree of control and thus protection, and are often subject to constant hunting pressures and other anthropogenic influences that affect the environment. In conclusion, we suggest that the Owl Monkey Reserve within this private ranch should be protected at a provincial level, since it comprises a large percentage of the mammals identified by the IUCN to belong to species that are vulnerable or endangered. In particular, various carnivores live in this reserve, whose regional conservation status is not well studied, like maned wolf, crab-eating fox, jaguarundi, Geoffroy's cat, ocelot, and puma; as predators, these species are very important for the ecosystem (Terborgh and Estes 2010). Within the EG the possibility should be evaluated to implement actions that try to eliminate, at least in the surroundings of the reserve, any remaining factors of possible disturbances of the ecosystem, such as access by cattle. Finally, it would be highly advisable to evaluate possible new private ranches that would like to join in protecting biodiversity so that the EG does not remain an isolated area, as is

the case with so many provincial or national parks and reserves.

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Authors' Contributions

MH, CJ, MR, VD, and EFD collected data and identified species; MH performed the analyses; MH, CJ, and EFD wrote the text.

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